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Optimizing Recognition and Management of Patients at Risk for Infection-Related Decompensation Through Team-Based Decision Making

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ABSTRACT

Introduction: Pediatric sepsis is a leading cause of death among children. Electronic alert systems may improve early recognition but do not consistently result in timely interventions given the multitude of clinical presentations, lack of treatment consensus, standardized order sets, and inadequate interdisciplinary team-based communication. We conducted a quality improvement project to improve timely critical treatment of patients at risk for infection-related decompensation (IRD) through team-based communication and standardized treatment workflow.

Methods: We evaluated children at risk for IRD as evidenced by the activation of an electronic alert system (Children at High Risk Alert Tool [CAHR-AT]) in the emergency department. Outcomes were assessed after multiple improvements including CAHR-AT implementation, clinical coassessment, visual cues for situational awareness, huddles, and standardized order sets.

Results: With visual cue activation, initial huddle compliance increased from 7.8% to 65.3% ($p < .001$). Children receiving antibiotics by 3 hours postactivation increased from 37.9% pre–CAHR-AT to 50.7% posthuddle implementation ($p < .0001$); patients who received a fluid bolus by 3 hours post-CAHR activation increased from 49.0% to 55.2% ($p = .001$).

Conclusions: Implementing a well-validated electronic alert tool did not improve quality measures of timely treatment for high-risk patients until combined with team-based communication, standardized reassessment, and treatment workflow.

Keywords: sepsis, communication, team, standardized treatment

Introduction

Pediatric sepsis is a leading cause of death among children, accounting for at least 7,000 deaths per year in the United States.[1] Pediatric sepsis is defined as (1) two or more age-based systemic inflammatory response syndrome criteria, (2) confirmed or suspected invasive infection, and (3) cardiovascular dysfunction, acute respiratory distress syndrome, or dysfunction of two or more noncardiovascular organ systems.[2-4] Many hospitals implement electronic tools to help in the early identification of patients with septic shock or other infection-related forms of deterioration.[5-7] These electronic tools augment clinical decision making by enabling earlier detection and intervention.[8] Pediatric sepsis diagnosis and treatment recommendations still lack consensus for how and when common treatments such as antibiotics and fluids are administered, leaving room for considerable practice variations.[9-11]

In pediatric sepsis, administering both intravenous (IV) antibiotics and an IV fluid bolus (IVFB) within one hour is associated with decreased mortality, whereas separate delivery of these elements is not.[12,13] These observations are consistent with studies showing that timely recognition and standardized clinical pathways improve outcomes, safety, and efficiency.[14-16] Additional studies establish that team communication and situational awareness are an integral part of mitigating patient risk.[17-19] Recognizing pediatric sepsis and delivering timely interventions remain challenging given the multitude of clinical presentations, lack of treatment consensus, and need for team-based communication.[9]

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A review of infection-related decompensation (IRD) safety events at our organization identified four common causes: delayed recognition, delayed treatment, suboptimal team communication/collaboration, and inadequate knowledge. In August 2017, we implemented a predictive electronic alert tool for children at high risk (Children at High Risk Alert Tool [CAHR-AT]) to address inadequate/delayed recognition.[6,7,20] The project we report here addresses delayed treatment and suboptimal team communication/collaboration.

This project combined two separately proven elements, an electronic alert tool (CAHR-AT) and team-based communication, to trigger recommended therapies and increase the relative percentage of patients receiving these critical treatments within 3 hours of CAHR-AT activation by 20%.[11]

Methods

Study Design and Setting

A quality improvement project involving three time epochs from August 2016 through December 2020 was undertaken at a 206-bed freestanding, urban, academic children's hospital with an annual emergency department (ED) volume of approximately 53,000 patients, designated as a Level 1 Pediatric Trauma Center. The Institutional Review Board approved this quality improvement project as nonhuman subjects' research. Cerner Millennium (Cerner Corporation, Kansas City, MO) was our primary electronic health record (EHR). We used the Model for Improvement framework and Toyota Problem Solving methodology to identify root causes, opportunities for improvement, and to test and implement changes throughout this project.[21,22] A key driver diagram (see Figure, Supplemental Digital Content 1, **http://links.lww.com/JHQ/A160**) guided the interdisciplinary team to improve timely critical therapies for patients at risk for IRD.

Selection of Patients

All patients with ED who activated the CAHR-AT were included in the analysis (see demographics Table, Supplemental Digital Content 2, **http://links.lww.com/JHQ/A161**). We evaluated three time epochs: (1) pre–CAHR-AT implementation (August 2016–July 2017), (2) initial CAHR-AT and workflow implementation (August 2017–December 2018), and (3) electronic huddle implementation (January 2019–December 2020). To establish the baseline intervention rate in CAHR+ patients before its real-time implementation, we analyzed retrospective ED data from August 2016 to July 2017. This allowed unbiased before and after comparisons of the effects of the CAHR-AT and other interventions. We assessed for performance changes during the second and third time epochs only.

The CAHR-AT algorithm (August 2017) used two target standards to define IRD as either severe sepsis within 48 hours of ED arrival or early sepsis within 24 hours of ED arrival that resulted in "major" or "extreme" severity of illness (SOI, a diagnosis-based index of maximum physiologic decompensation during the hospital stay).[4,6,20,23] We chose to use the terminology "IRD" instead of "sepsis" for two reasons: (1) this definition facilitated earlier recognition of patient deterioration and (2) this definition identified a broader patient population because sepsis alone is typically an infrequent occurrence and listing "sepsis" as a discharge diagnosis is uncommon (1.8% of CAHR-AT activations).

Iterative Improvements and Related Analyses

During the project, the CAHR-AT algorithm was updated multiple times to improve sensitivity and positive predictive value.[20] Associated workflows implemented focused on improving team-based assessment/reassessment and communication, situational awareness, and standardized treatment bundles.

Because the CAHR-AT identified a broad range of at-risk patients, the team developed a new visual branding that better emphasized its capabilities, changing from "Pediatric Sepsis Screening Tool" to "Children at High Risk Alert Tool (CAHR-AT)," which shifted the focus from predicting only sepsis to predicting general IRD within 48 hours of ED arrival[20] (see Supplemental Digital Content 2 (Table, **http://links.lww.com/JHQ/A161**) for the top five CAHR-AT diagnostic groups). Children at High Risk Alert Tool activation generated two distinct elements: the score which indicated the risk of decompensation (the higher the score, the more likely "major" or "extreme" SOI would occur) and the stoplight color, which indicated patient status.[20] The CAHR-AT score was recalculated when new data were entered by adding up weighted values for each of 13 factors obtained from the EHR such as vital signs, laboratory values, and medical history.[20] Staff were alerted by a checkered flag displayed on the Cerner ED tracking board if the score was five or greater, which indicated a children at high risk positive (CAHR+) patient. Tracking board

information was visible to all ED staff including providers, nurses, registration, and consulting providers. The most recent CAHR score appeared next to the patient on the ED tracking board for situational awareness of risk.

A checkered flag indicated the need for a CAHR assessment. The workflow required a provider (Doctor of Medicine/Nurse Practitioner) and nurse (hereafter known as "dyad") to jointly assess the patient at the bedside within 10 minutes of the CAHR-AT activation. After assessment, the dyad agreed on a care plan and stoplight color (red, yellow, or green). The color indicated their clinical assessment of the patient's status, resources needed, and frequency of dyad reassessment (Figure 1). The dyad completed their respective CAHR assessment forms in the EHR. The nurse acknowledged assessment completion and recorded the provider's name; the provider selected the agreed-on stoplight color and documented the nurse's name to generate accountability. On completion of both forms, the chosen stoplight color displayed on the ED tracking board for situational awareness (Figure 2), making the team aware of both assessment completion and the patient's current risk assessment.

In addition to indicating the patient's status and resource utilization urgency, treatment bundles associated with each stoplight color were recommended to address delayed interventions and connect standardized treatment to team assessment workflow (see Figure, Supplemental Digital Content 3, **http://links.lww.com/JHQ/A162**, the huddle treatment guide). We derived recommended treatment time intervals from CAHR activation to IV or intramuscular (IM) antibiotics and IVFB administration (see Figure, Supplemental Digital Content 3, **http://links.lww.com/JHQ/A162**) from the existing pathway guidelines for patients at risk for decompensation because of infection within the ED, such as patients with neutropenia, sickle cell

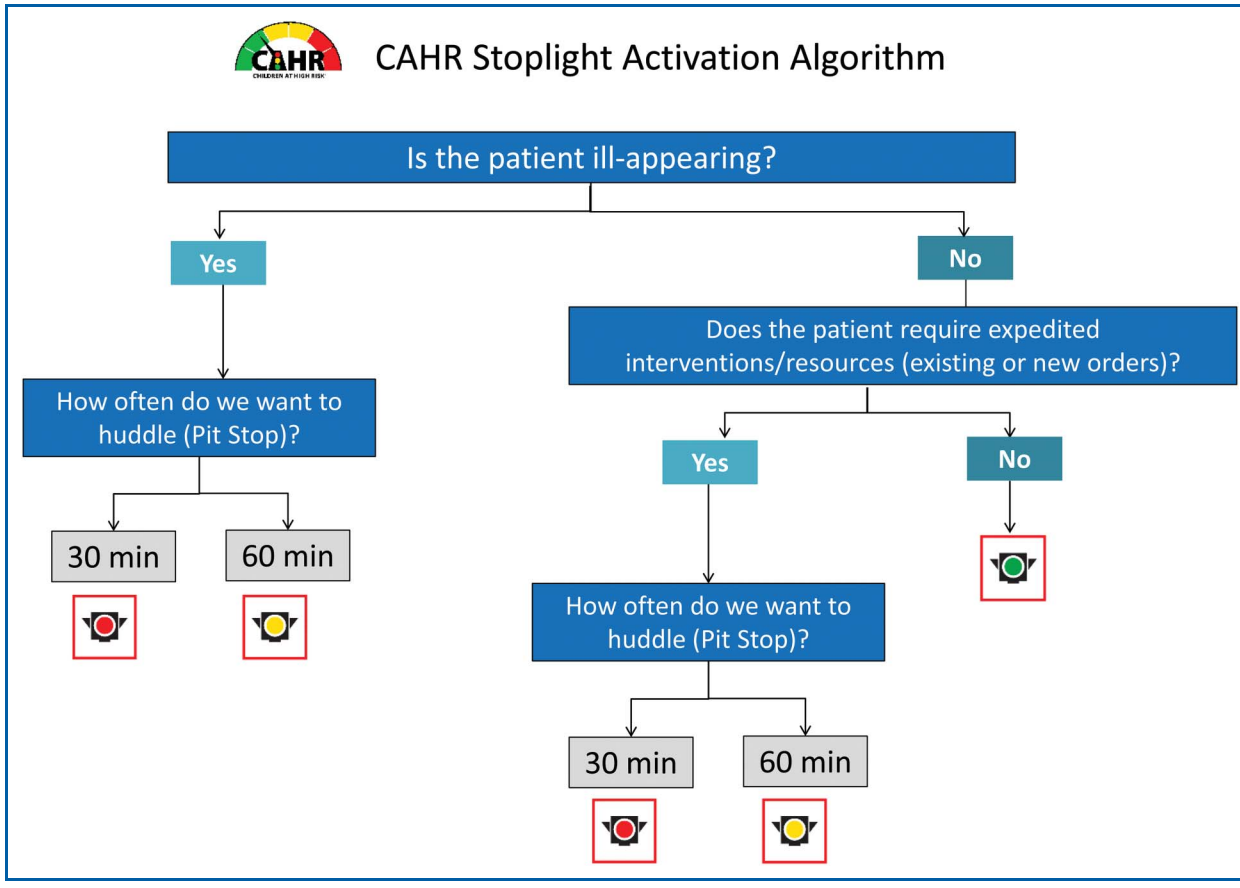

Figure 1. Stoplight activation algorithm used to determine stoplight color during dyad huddle. CAHR = Children at High Risk.

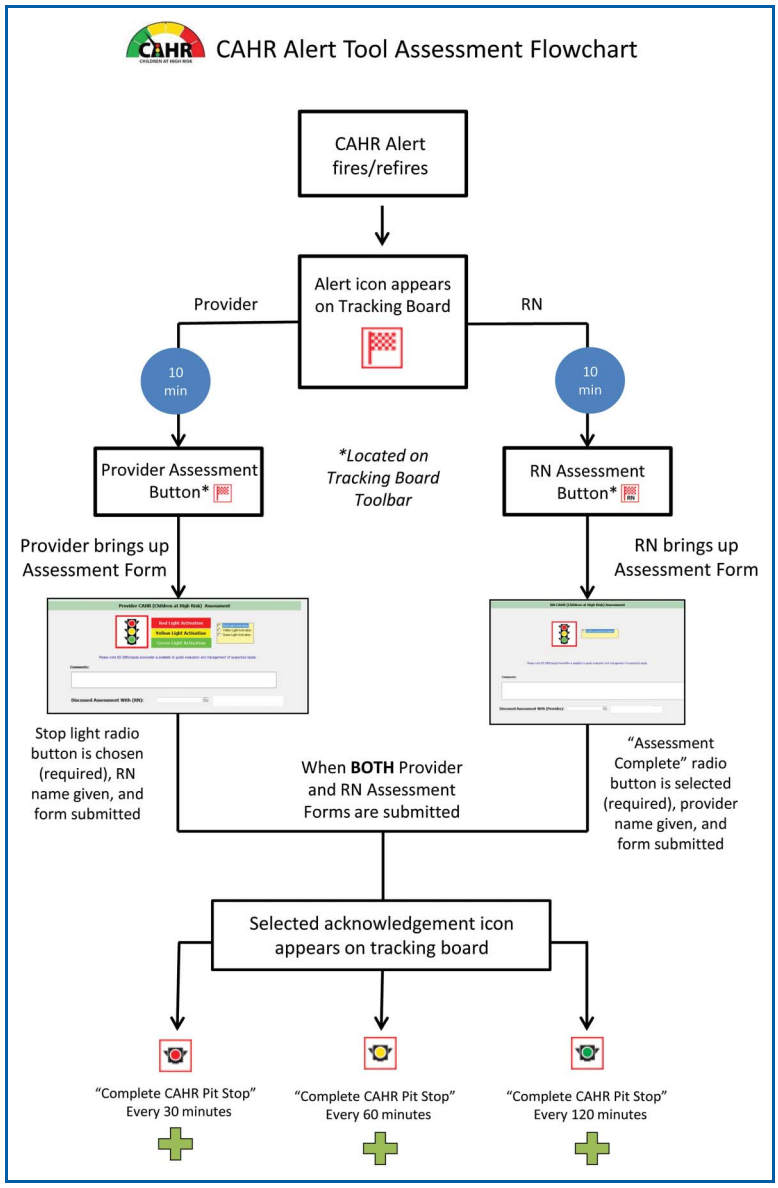

Figure 2. CAHR-AT assessment flowchart showing the emergency department workflow related to the CAHR-AT. CAHR-AT = Children at High Risk Alert Tool; RN = registered nurse.

anemia, or febrile neonatal patients. Emergency department clinicians suggested additional bundle elements, such as diagnostic testing, assessment frequency, and optimal monitoring needs. We initiated a plan-do-study-act (PDSA) cycle to improve team reassessment of CAHR+ patients at a designated frequency based on their assigned stoplight color (Figure 2), which the team originally documented on paper.

Following the PDSA, the project team implemented an electronic version of the huddle workflow (January 2019). On assigning a stoplight color from the initial dyad assessment, a nursing task appeared in the events column on the ED tracking board at frequencies of 30, 60, or 120 minutes, depending on the color chosen (Figure 2). During each subsequent huddle, the dyad reassessed the patient, communicated progress of care plan implementation, and reevaluated the care plan. If appropriate, the huddle was also used to change the stoplight color to reflect current patient status more accurately. The only other time a stoplight color changed was if the CAHR score increased because of new abnormal values for one or more of the 13 EHR factors evaluated,

prompting another checkered flag and dyad assessment (Figure 2).

To standardize treatment, ED red and yellow stoplight order sets were developed based on the previously suggested stoplight bundles (see Figure, Supplemental Digital Content 3, **http://links.lww.com/JHQ/A162**).

To obtain feedback during the project on the perceived impact of process improvements on their workflow and patient care, a subjective electronic anonymous survey was distributed to ED staff including providers, nurses, clinical technicians, and administrative support staff.

Method of Analysis

We analyzed initial huddle compliance in CAHR+ patients to assess process improvements related to team-based communication. To measure treatment-related outcomes, we analyzed the percentage of CAHR+ patients who received specific bundle elements (IV/IM antibiotics and IVFBs) by 3 hours post–CAHR-AT activation and the percentage of CAHR+ patients with ED collected bacterial cultures. Only bacterial cultures for blood, urine, cerebral spinal fluid, or fluid from a presumed sterile cavity were included. Although our internal goals were to administer these bundle elements within one hour, we analyzed the data based on more widely accepted published recommendations for antibiotic administration within 3 hours.[10,24]

Manual CAHR+ chart evaluations were completed to identify the percentage of patients who received either IV/IM antibiotics or an IVFB at an outside facility before arriving in the ED or when the EHR was offline. To ensure consistency in chart reviews, randomly selected charts were examined by all reviewers as a teaching aid to assess interrater reliability.

All data were analyzed using statistical process control charts created using Minitab Statistical Software v.19 (State College, PA). Data from the first and last time epochs were also analyzed using an exact chi-square test.

Results

The CAHR-AT currently activates on ~2.0% of ED arrivals where the positive and negative predictive values for high SOI outcomes were 22.5% and 98.7%, respectively.[20] Characteristics of the patients who activated the CAHR-AT during the three epochs are shown in Supplemental Digital Content 2 (see Table, **http://links.lww.com/JHQ/A161**). Between August 2017 and December 2020, the initial stoplight colors for 3,630 CAHR+ patients were red 6.7%, yellow 61.5%, and green 31.7%.

Team-Based Communication Process Measures

Compared with the paper-based second time epoch, communication, situational awareness, and team-based assessment improved after electronic implementation of huddle workflow; initial huddles increased from 7.8% to 65.3% for CAHR+ patients with either a red or yellow stoplight activated ($p < .0001$; Figure 3). Clinical teams completed an initial huddle 70.8% of the time for red stoplight designation, 60.5% for yellow, and 26.1% for green. Figure 3 data exclude patients with the highest level of acuity because providing immediate clinical attention took precedence over huddle documentation (see Table, Supplemental Digital Content 2, **http://links.lww.com/JHQ/A161**, for acuity data). For all other CAHR+ patients, the clinical team should complete and document an initial huddle every time.

The electronic survey showed 69% of ED staff agreed that communication during huddles improved patient care, whereas 2% disagreed. In addition, 71% agreed and 0% disagreed that the new CAHR processes have or are beginning to improve communication within the care team. A total of 48 ED staff responded to the survey, approximately 50% of all ED nurses and providers.

Treatment Outcome Measures

The percentage of CAHR+ patients with ED collected bacterial cultures increased from 45.3% pre–CAHR-AT to 56.4% postelectronic huddle workflow (24.5% relative increase; $p < .001$; see Figure, Supplemental Digital Content 4, **http://links.lww.com/JHQ/A163**). CAHR+ patients who received IV/IM antibiotics by 3 hours post–CAHR-AT activation increased from 37.9% to 50.7% (33.7% relative increase; $p < .0001$; Figure 4A), while the percentage of CAHR+ patients who received an IVFB by 3 hours post-CAHR activation increased from 49.0% to 55.2% (12.7% relative increase; $p = .0009$; Figure 4B). Apart from IVFB administration, we met our aim of improving the timeliness of critical treatments by 20% of the preimplementation baselines.

Limitations

There were several limitations to this project. It is unknown how this alert tool and its associated workflow would perform at other institutions. Our

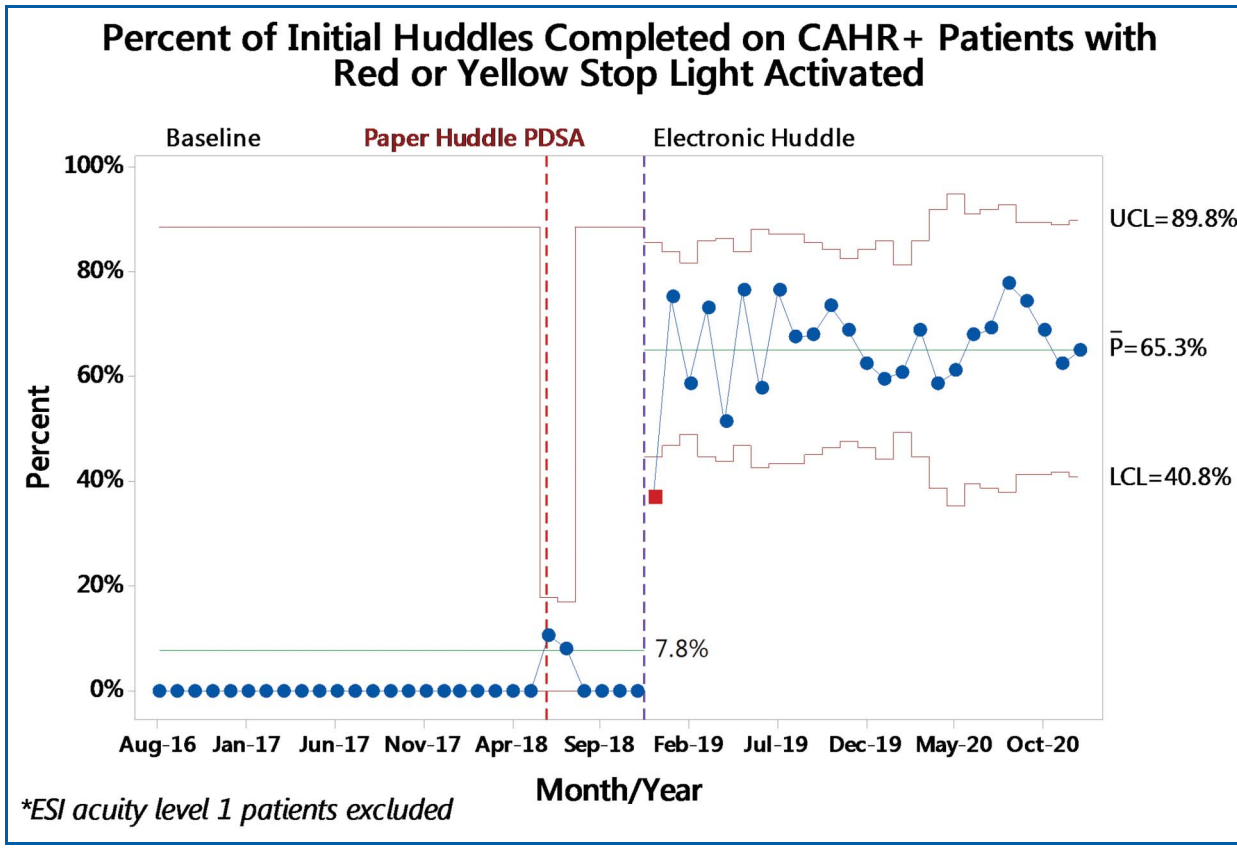

Figure 3. Percent of CAHR red and yellow light patients with an initial dyad huddle completed. CAHR = Children at High Risk.

method of evaluating this population as IRD may not translate to other health systems because of differences in electronic data availability and patient populations.[4,20]

Some patients receive antibiotics and IVFBs before arrival, and our current transport and in-hospital charting systems do not communicate with each other. Manual chart reviews were required to ascertain that ~7% of CAHR+ patients received antibiotics at an outside hospital because of missing EHR documentation.

Currently, the CAHR-AT only accepts the provider's stoplight color designation. Occasionally, clinicians disagreed on the stoplight color designation, especially for noncritically ill patients. In these situations, nursing generally favored a higher risk designation compared with providers. This limitation may have leveled patients at a lower risk than nursing felt was appropriate. We will consider adding the stoplight selection capability for nursing. Evaluating CAHR-AT+ patients through admission might help determine the effect of ED treatment on patient outcomes.

Discussion

This project demonstrated that implementing an EHR-based tool to identify children at risk for IRD did not result in improved treatment-related outcomes until accompanied by standardized team huddles and reassessments, team-based decision making, and standardized treatment bundles.

Most other electronic alert tools attempt to aid in identifying active sepsis, making scoring more likely to align with the patient's status, and are not intended to be predictive.[5,8,25,26] The CAHR-AT's predictive nature presented a cultural hurdle that took time and patience to overcome because it was not indicating active IRD. Because ED clinical staff focus on current presentation and prioritize accordingly, it was challenging for staff to consider input from a tool that predicted an outcome up to 48 hours into the future, especially if the patient did not appear seriously ill. Therefore, future implementation on inpatient units may have fewer cultural hurdles to overcome. Despite initial ED provider hesitancy to rely on the CAHR-AT to guide their practice, the increase in bacterial

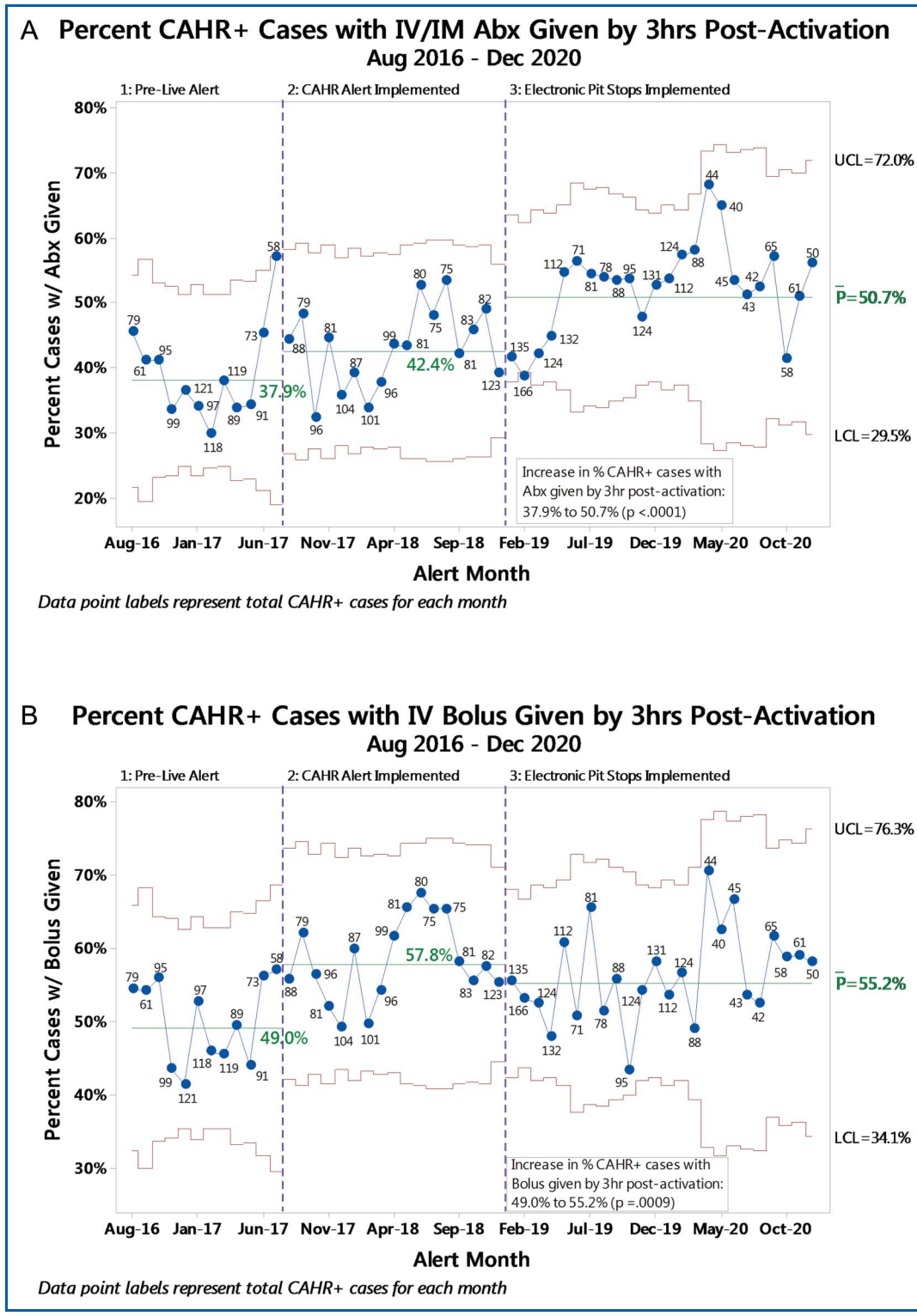

Figure 4. A, Percent of patients with CAHR-AT activation who received IV/IM antibiotics by 3 hours post-activation. B, Percent of patients with CAHR-AT activation who received IVFB by 3 hours postactivation. CAHR-AT = Children at High Risk Alert Tool; IM = intramuscular; IV = intravenous; IVFB = IV fluid bolus.

culture ordering showed a positive shift toward considering sepsis or other infection-related diagnoses more frequently. This shift likely resulted from implementation of consistent standardized huddles and the resulting collaborative decision making. To further gain stakeholder support, we used newsletters, 1:1 check-ins, and regular meetings.

Changing the alert tool name may have helped decrease diagnostic bias. With the focus initially on sepsis only, providers believed the tool was unreliable when the patient was not found to be septic. Rebranding encouraged critical thinking to consider a broader range of infection-related diagnoses.

Transitioning toward standardized team-based assessment and communication changed both physical workflow and the individualized, impromptu communication style common in the ED. Despite the CAHR-AT indicating a high-risk patient, staff inconsistently coordinated recurrent huddles, especially when perceived urgency was low, such as patients with a yellow or green stoplight. After electronic huddle implementation, it took approximately 6 months to see decreased variation in huddle coordination. Ongoing ED staff feedback about instances where they were not in compliance with the new workflow helped illustrate the value of team-based reassessments and standardized treatment bundles. This shifted the ED toward a culture of high reliability. Before electronic huddle implementation, interdisciplinary communication was disjointed and often required excessive time for effective nurse provider communication. Afterward, real-time joint decisions helped develop a sense of unity between nurse, provider, and patient/family. Over time, both providers and nurses took more initiative to complete the huddle in the required timeframe. Although it is common to include an initial huddle for institutions with sepsis alert tools, implementation of standardized reassessments for at-risk patients, as performed in this project, has not been reported to our knowledge.[5,8,25] As demonstrated through surveys and Figure 3, the team learned that consistent huddle completion allowed for real-time adaptations in care as the illness progressed or the response to treatment became evident.

Standardized order sets optimize care delivery and outcomes and improve patient safety which, in turn, prevents therapeutic miscues and reduces time to intervention.[15] Huddles served as a roadmap for discussions about potential treatment strategies and along with treatment bundles, contributed to significant improvements in timely IV/IM antibiotic and IVFB administration and bacterial culture orders.

Compared with IV/IM antibiotic administration, improved delivery of an IVFB by 3 hours postactivation was modest. Providers expressed hesitance ordering IVFBs without evidence of abnormal perfusion or hypotension, despite some literature recommending bundle administration for this high-risk population.[13] However, manual chart reviews found that many children who did not receive an IVFB received maintenance IV fluids. As stated in the Pediatric Surviving Sepsis Guidelines (2020), "fluid bolus therapy in children with moderate hypotension was not beneficial or harmful compared with maintenance fluid only."[10] These fluid guidelines considered the presence of septic shock and resource availability, while other literature suggests benefits of bundle administration that includes IVFB, leading individual clinicians to adopt different approaches.[10,13,27] Disagreement persists around the best approach in the administration of IV fluids for patients with IRD.

We maintained an expectation of antibiotic administration within one hour from completion of the dyad assessment for consistency in practice. However, we chose to analyze the data based on the three-hour published recommendations for antibiotic administration to improve the applicability of our findings to other organizations. A one-hour goal may have contributed to the significant increase in IV/IM antibiotic administration. The 33.7% relative improvement in IV/IM antibiotic administration from the preproject baseline is evidence of a shift in ED culture toward considering IRD in the differential diagnosis and proactively treating patients. This improvement magnitude aligns with other health systems, such as the 20% improvement in antibiotic administration times described by Lockwood et al[28] after introducing a sepsis response system. In retrospect, expecting antibiotics and IVFBs within one hour, without being hemodynamically compromised, may be unrealistic, especially considering the predictive accuracy of the CAHR-AT. In the future, we could increase our goal to 3 hours as other studies recommend while maintaining optimum outcomes.[10,23,29] To further improve patient outcomes, a more consistent approach to treatment, including all bundle elements, should be adopted.

Conclusions

Although an electronic alert tool may improve early identification of children at high risk, improved timeliness of critical treatments for children at high

risk for IRD only occurred when the alert tool was supplemented with standardized team-based assessment and communication, shared situational awareness, and implementation of standardized treatment protocols.

Implications

Cumulatively, team-based communication and standardized treatment increase the consideration of a broad range of infection-related diagnoses, increasing compliance and timeliness of treatment-based interventions. Together, these interventions improve the number of at-risk patients who receive initial huddles and timely treatment. Standardized reassessments encourage multidisciplinary discussions about the signs and treatment of IRD and aid in discouraging cognitive bias by considering different caregiver assessments.

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